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OPERATIONAL NOTE

A MOBILE APP FOR MILITARY OPERATIONAL ENTOMOLOGY PESTICIDE APPLICATIONS

SETH C. BRITCH,[1] KENNETH J. LINTHICUM,[1] ROBERT L. ALDRIDGE,[1] MATTHEW W. YANS,[2] DAVID W. HILL,[3] PETER J. OBENAUER[2] AND ERIC R. HOFFMAN[2]

ABSTRACT. Multiple field studies conducted for the Deployed War-Fighter Protection (DWFP) research program have generated more than 80 specific guidance points for innovative combinations of pesticide application equipment, pesticide formulations, and application techniques for aerosol and residual pesticide treatments in 6 ecological regions against a range of mosquito, sand fly, and filth fly nuisance and disease-vector threats. To synthesize and operationalize these DWFP field and laboratory efficacy data we developed an interactive iOS and Android mobile software application, the Pesticide App, consisting of specific pesticide application guidance organized by environment and target insect vector species.

KEY WORDS iOS, Android, pesticides, vector control, Deployed War-Fighter Protection research program

The Deployed War-Fighter Protection (DWFP) research program directed by the Armed Forces Pest Management Board (AFPMB) has for more than 10 years investigated specific military problems relevant to the Department of Defense (DoD) pest management system (Linthicum et al. 2007, Kitchen et al. 2009, Avant 2012, Burkett et al. 2013), in particular evaluating and developing innovative enhancements of key operational entomology components such as aerosol and residual pesticide applications. The need for this research emerged in part from observations that standard pest management approaches were not effective against sand flies during recent US military operations in Iraq (Coleman et al. 2006, 2011). Despite expectations of universal efficacy, the majority of pesticide formulations, application equipment, and pest management techniques have been developed in laboratory or semifield conditions targeting a limited variety of species of colony insects, and tested in limited field trials in a single ecological region, the southeast USA, with limited scientific validation. The DWFP research program has generated more than 80 operationally relevant guidance points for innovative combinations of equipment, formulations, and techniques for aerosol and residual pesticide treatments in 6 ecological regions against a range of mosquito, sand fly, and filth fly nuisance and disease-vector threats. The resources of the program have made it possible to carry out trials with identical combinations of pesticides and equipment across a variety of environments, and thus develop a database of relative efficacy that may substantially improve outcomes of military (and possibly civilian) operational pest management activities worldwide. The DWFP field research has emphasized use of existing materiel from the military inventory or commercial off-the-shelf products and precision use of equipment and formulations that maximize efficacy and minimize exposure of humans and the environment to pesticides.

Data and innovations from DWFP research are captured in reports, publications, web repositories, and presentations (e.g., Farooq et al. 2010; Britch et al. 2009, 2010a, 2010b, 2011a, 2011b; Aldridge et al. 2012, 2013; Doud et al. 2014; Dunford et al. 2014). However, lag time between reporting innovations and incorporating them into military or civilian operational doctrine is prohibitive, and there has not yet been a simple, comprehensive synthesis of DWFP data accessible in the field to medical entomologists, pest management operators, or instructors and their students. Traditional syntheses of operationally relevant scientific findings such as technical bulletins, field manuals, or pocket guides are poor at capturing and communicating new or updated information, are slow and expensive to edit and update, and even when posted electronically to the Internet require users to find and download them one by one and remember to check for updates. From a practical standpoint for field operations paper-based media are bulky and inconvenient, while mobile devices such as smart phones and tablets are pervasive. Here we describe the development of a mobile device

[1] US Department of Agriculture, Agricultural Research Service, Center for Medical, Agricultural, and Veterinary Entomology, 1600 SW 23rd Drive, Gainesville, FL 32608.

[2] Navy Entomology Center of Excellence, Naval Air Station, PO Box 43, Jacksonville, FL 32212.

[3] Department of Defense Armed Forces Pest Management Board, US Army Garrison-Forest Glen, 2460 Linden Lane, Silver Spring, MD 20910.

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14. ABSTRACT

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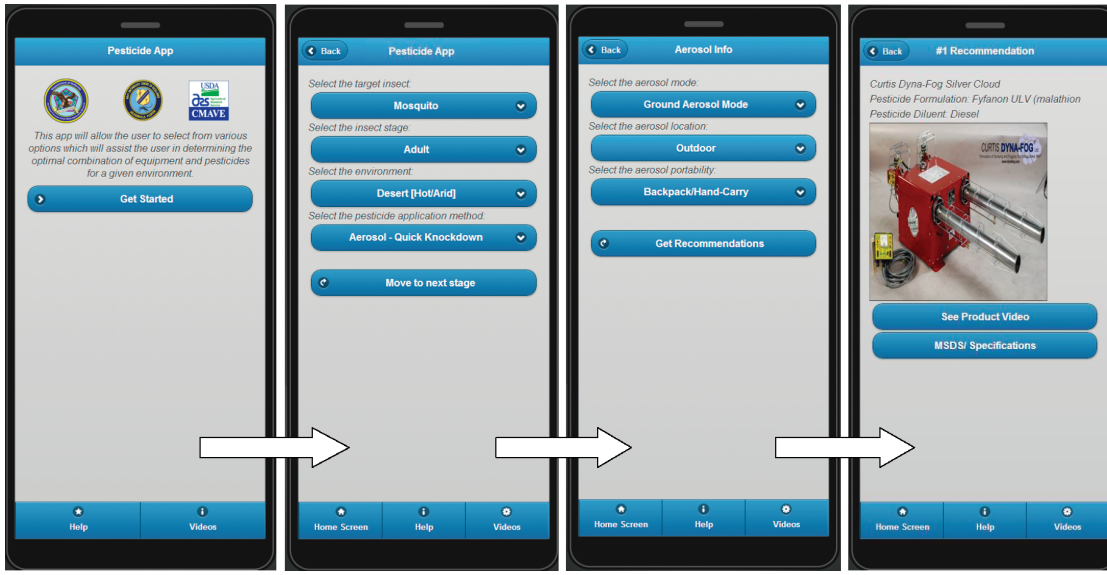

Fig. 1. Sample screen shots of the iOS version of the Pesticide App showing (left to right) the home screen with start button; the basic data screen with choices for target insect, insect life stage, environment, and pesticide application method; the advanced data screen with additional choices relevant to pesticide application method such as aerosol mode and location; and the recommendation screen showing an optimal combination of pesticide formulation and application equipment. The app provides environment-specific and target insect-specific guidance for use and configuration of pesticides and pesticide application equipment depending on the initial conditions set by the user on these and subsequent screens.

application, the Pesticide App, which incorporates DWFP research data and innovations and provides specific pesticide application guidance organized by environment and target insect species.

The Pesticide App for the iOS platform was developed using the cloud-based service Appery.io (http://appery.io/) and was developed on the Android platform using the open-source software App Inventor (http://appinventor.mit.edu/explore/). The Pesticide App is stable and uses less than 50 MB, with a draw on bandwidth and battery life similar to apps of comparable size. A beta version of the app is available at http://www.afpmb.org/content/pesticideapp and http://www.ars.usda.gov/Business/docs.htm?docid=24908, and the final version will be available on the Apple App Store. The app consists of object-oriented databases of pesticide formulations and application equipment linked to environment- and target insect-specific aerosol and residual pesticide application guidance points driven by DWFP generated real-world field and laboratory data. A *guidance point* consists of an aerosol or residual *technique* and its *expected efficacy*. A *technique* is a specific combination of pesticide (and diluent) and pesticide application equipment used against a target insect at a given life stage, in a given ecological zone and environmental conditions. The *expected efficacy* is expressed as the frequency of target insect mortality or population reduction observed in a field trial of the technique.

The Pesticide App is initiated from the home screen which contains the start button in addition to links and contact information for the agencies responsible for developing the application and links to instructions for using the application (Fig. 1). The start button leads the user to drop-down menus to enter a series of variables that will be used by the app to determine and display guidance. The initial user-defined variables are the target organism (mosquito, sand fly, or filth fly) and its life stage (larval or adult), the environment in which the pesticide application will take place (desert/hot-arid, temperate/warm-humid, or tropical/hot-humid), and whether aerosol/quick knockdown or residual/long-term control methods will be used. If aerosol is selected, the user is prompted to indicate aerial or ground application, and ultra-low volume or thermal fog. In the case of ground applications, the user is also asked whether the application will be indoor or outdoor, or whether a misting system will be used. If residual is selected, the user must indicate whether the mode of application will be standard cold mist, electrostatic cold mist, thermal fog, or foam, and whether the treatment will be indoor or outdoor. If the application will be outdoor residual, the user then selects the substrate; current options include desert camouflage netting, woodland camouflage netting, HESCO material, vegetation (desert or temperate), and rodent burrow (soil). The final group of user inputs is whether the pesticide formulation

needs to be synthetic, botanical, or biological and whether oil- or water-based. Formulations are further divided; for instance, synthetic options may include pyrethroid, organophosphate, or neonicotinoid. The user then selects "Get Guidance," and the app will return a screen showing 3 horizontal color-coded panels, the top one marked with green (highly effective), the middle amber (moderately effective), and the bottom red (minimally effective or ineffective; not recommended). Each panel will contain text indicating a pesticide and a piece of equipment.

Expected efficacy is derived differently depending on aerosol or residual treatments. For an aerosol technique, for example, high efficacy may be indicated by >80% mortality in sentinel mosquitoes up to 100 m from the spray line. For a residual technique on the other hand, high efficacy may be indicated by >60% reduction in wild sand flies for >6 months. The Pesticide App is naturally limited by available data and so will become more comprehensive over time. Certain combinations of user inputs may return "No Data Available" until field studies are completed. In some cases, guidance may consist of only a single green, amber, or red panel or 2 panels if sufficient studies have not been carried out. Users may not have the specific pesticide and/or equipment indicated in the guidance, but may weigh the guidance in choosing similar available materials.

With the published and unpublished DWFP data currently available, the Pesticide App is immediately field operational and will provide specific guidance to users in desert, tropical, and temperate ecological zones for a range of pesticides, application equipment, and techniques. Once uploaded and installed on an iOS or Android mobile device the Pesticide App works independently of wireless service. This is an important feature for military use where operations may take place in remote, austere conditions with limited Internet connectivity, and initial loading and familiarization with the app may be carried out as part of premission preparations. The current configuration of the app is designed for a user with skills and training in pest management who is expected to understand and have data for the user inputs described above. However, future versions of the app will have a greater variety of choices from the home screen to guide a more diverse population of users. This may be accomplished by simply adding the option to pick "unknown" for any of the initial conditions. For instance, a user could begin by only selecting the ecological zone and the insect that needs to be controlled, and selecting "unknown" for the remaining initial conditions, and the user will be guided through a spectrum of aerosol and residual methods that could be used. In this way the app becomes an instructional tool and could be used, for example, as a guide to building a vector control program from the ground up, with recommendations and options specific to the environmental conditions or legal or financial restrictions that the user must consider.

The basic Pesticide App will be enhanced by a variety of user-selected supplemental information expansion packs that may be loaded when an Internet connection is available. The 1st expansion pack consists of application equipment manuals and pesticide formulation material safety data sheets and labels relevant to all guidance points in the app, pesticide use reporting forms such as the US military DD Form 1532, and a link to the Arthropod Pesticide Resistance Database (http://www.pesticideresistance.com/). The expansion pack will also link to 2 US Department of Agriculture iOS apps, the "Vector Sprays" and "Aerial Sprays" apps (O'Brien 2012), which provide data on nozzles, pressure, flow rates, and droplet spectra for a variety of pesticide application equipment and pesticide formulations. Data in this expansion pack may be accessed directly from the color-coded guidance panels that present recommended pesticide/machine combinations. The 2nd expansion pack consists of primary literature relevant to the DWFP research that drives the app, as well as a selection of relevant AFPMB publications such as technical guides, DoD guidance and instruction documents, disease vector ecology profiles, and pesticides and materiel lists. The 3rd expansion module connects the user, when wireless service is available, to information and alerts from vector and/or vector-borne disease monitoring and warning systems such as "The Rift Valley Fever Monitor" (http://www.ars.usda.gov/Business/docs.htm?docid=23464), "The Malaria Atlas Project" (http://www.map.ox.ac.uk/), Pro-Med Mail (http://www.promedmail.org), and "VectorMap" (http://www.vectormap.org/). Each of these packs increases the size of the app; however, users can install or remove them depending on available device memory or needs of the mission.

Software updates, bug fixes, and new features may be installed into the core Pesticide App at any time and pushed globally in near real time to all users via Apple and Android App stores to enable a pesticide use guidance system that is perpetually relevant and based on the latest information. The object-oriented database structure underlying the app efficiently captures small or large corrections, developments, or new information. The app master will ensure that all expansion modules are up to date and will routinely replace publications, links, and other materials with the most recent versions, or add new ones, so that current expansion packs, in addition to app updates, may be pushed to users when Internet connections are available.

Future additions to the app will include guidance points from non-DWFP scientific literature to fill

the gaps in target arthropods, techniques, pesticides, equipment, and environmental zones not currently investigated by DWFP projects. By combining DWFP and non-DWFP data, the app could have enough information to provide information to the genus or species level instead of the current family level. Future enhancements will also include a feedback loop within the app for users to report efficacy data, observations, or critique from the field for particular guidance points, or to comment on the app itself. Feedback will be compiled and merged into future guidance, for example, by displaying an efficacy repeatability score for each guidance point that will help users and DWFP researchers evaluate original research findings. User contributions to the app may also include comments on pesticide application equipment under real-world operational field conditions to balance manufacturers' claims or findings from semifield equipment trials and may include comments on reliability or common problems and workarounds. Users may also contribute guidance points for innovative or improved techniques or for efficacy observations in ecological zones or species-level insect targets that have not yet been investigated by DWFP or other research. Future versions of the app will also include suggestions for possible equivalent formulations or equipment that may be queried if users do not have access to those indicated in the guidance.

With the synthesis, guidance, and constantly evolving content in the Pesticide App, diverse users at a range of skill levels can find the most cost-effective and efficient methods for their needs. For example, highly varied and mobile military operational pest management activities in particular will benefit from methods that are effective across multiple environments or target species, or that include formulations effective in an array of machines, or machines effective with an array of formulations—information that has been captured in this app. The native flexibility and responsiveness of the Pesticide App information system will maintain and communicate effective nuisance and disease-vector insect control strategies despite current and future changing climates and shifting environments.

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